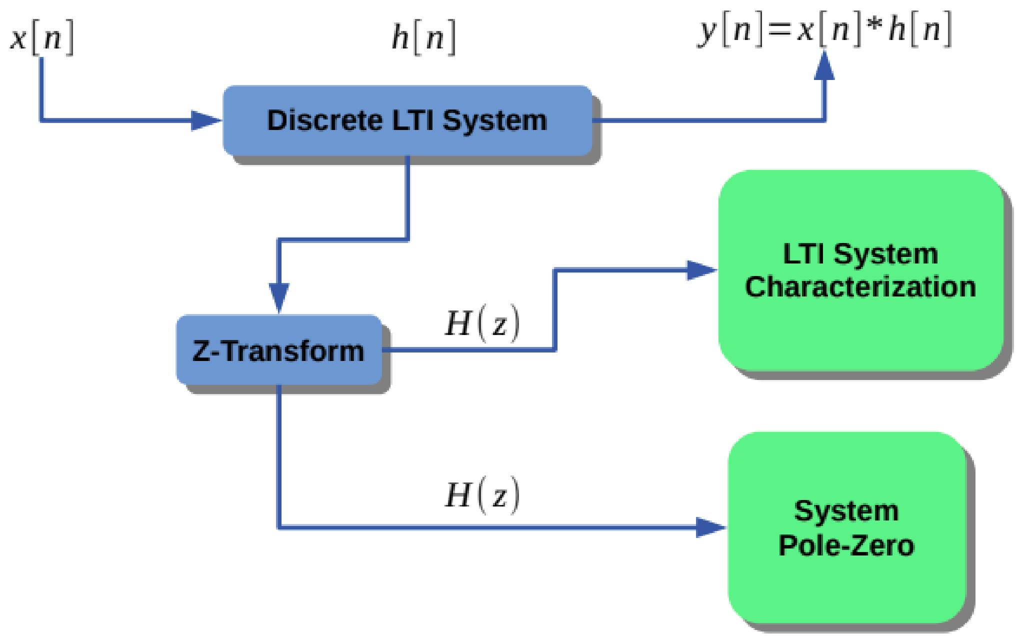
Experiment No : 6

Title : Z-transform of various sequences - verification of the properties of Z-transform

Objective : 1. Compute the Z Transform
2. Plot the pole and zeros of discrete LTI system
3. Find the frequency response of discrete LTI system

Block Diagram :



Code :

```
# Day6
# Z - Transform and DFT

# Import necessary modules
import dsp_module_custom  as dsp
import numpy as np
import matplotlib.pyplot as plt

# Define the numerator and denominator coefficients for the transfer function
b = np.array([1]) # Numerator coefficients
a = np.array([1, -0.6, 0.8]) # Denominator coefficients

# Calculate poles, zeros, and gain of the transfer function
```

```
z, p, k = dsp.tf2polezero(b, a)

print(" Zeros are at {}".format(z))
print(" Poles are at {}".format(p))
print(" Gain is : {}".format(k))

# Calculate frequency response
w, H = dsp.polezero2freq_response(z, p, k)

# Define signal parameters
Fs = 16000
w1 = 1.25
w2 = 2.5
F1 = Fs * (w1 / (2 * np.pi))
F2 = Fs * (w2 / (2 * np.pi))

# Define time parameters for the signal
Td = 5e-3
t = np.arange(0, Td, 1 / Fs)

# Generate the signal with two sinusoids
x = 1 * np.sin(2 * np.pi * F1 * t) + 1 * np.sin(2 * np.pi * F2 * t) # Creating the signal
# We are removing parts of signal with low gain; in this case, it is w2 where gain
is low or attenuation

# Apply the filter to the signal
y = dsp.linearfilter(b, a, x)

# Plotting the frequency response, original signal, and filtered signal
plt.figure(figsize=(20, 4))
plt.subplot(2, 2, 1)
plt.plot(w, np.abs(H)) # Taking absolute value since complex values for
frequency response
plt.xlabel("w (rad/sample) ---->")
plt.ylabel("|H(w)| ---->")
plt.title("Amplitude Plot")
plt.grid()

plt.subplot(2, 2, 3)
plt.plot(w, np.unwrap(np.angle(H))) # Fixing sudden phase changes like 360 +
15, similar to 360
plt.xlabel("w (rad/sample) ---->")
plt.ylabel("<H(w) ---->")
plt.title("Phase Plot")
plt.grid()

plt.subplot(2, 2, 2)
```

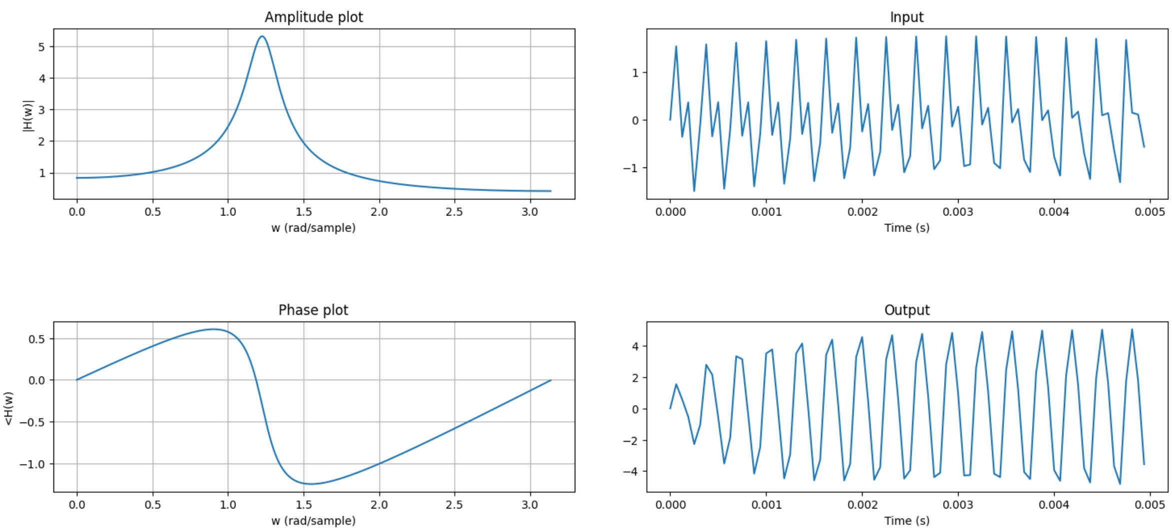
```
plt.plot(t, x) # Plotting the original signal

plt.subplot(2, 2, 4)
plt.plot(t, y) # Plotting the filtered signal

# Adjusting the layout for better visualization
plt.tight_layout()
plt.show()
```

Output :

Zeros are at []
Poles are at [0.3+0.84261498j 0.3-0.84261498j]
Gain is : 1.0



Custom Module used for the code :

```
# dspmodule.py

import numpy as np
from scipy.signal import freqz
from scipy.signal import lfilter


def tf2polezero(numerator_coeffs, denominator_coeffs):
"""
Calculate zeros, poles, and gain from numerator and denominator coefficients.

Parameters:
numerator_coeffs (array-like): Numerator coefficients of the transfer function.
denominator_coeffs (array-like): Denominator coefficients of the transfer
function.

Returns:
zeros (array): Zeros of the transfer function.
poles (array): Poles of the transfer function.
gain (float): Gain of the transfer function.
"""
num = numerator_coeffs
den = denominator_coeffs
zeros, poles = np.roots(num), np.roots(den)
gain = num[0] / den[0]
return zeros, poles, gain

def polezero2freq_response(zeros, poles, gain, num_points=512):
"""
Calculate the frequency response (H) from zeros, poles, and gain.

Parameters:
zeros (array-like): Zeros of the transfer function.
poles (array-like): Poles of the transfer function.
gain (float): Gain of the transfer function.
num_points (int, optional): Number of points for frequency response
calculation.

Returns:
w (array): Digital frequencies (omega).
H (array): Frequency response.
"""
w, h = freqz(b=np.poly(zeros), a=np.poly(poles), worN=num_points)
H = gain * h
return w, H
```

```
def linearfilter(b, a, x):
"""
Apply a linear filter to the input signal.

Parameters:
b (numpy.ndarray): Numerator coefficients of the filter.
a (numpy.ndarray): Denominator coefficients of the filter.
x (numpy.ndarray): Input signal.

Returns:
numpy.ndarray: Output signal.
"""
b = np.atleast_1d(b)
a = np.atleast_1d(a)
x = np.array(x).flatten()
y = lfilter(b, a, x)
return y
```